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The effect of STEM activities developed within the scope of a science course on 7th grade students' inquiry and innovative thinking skills

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Abstract

In this research, it is aimed to examine the effect of STEM activities developed within the scope of a science course on the inquiry and innovative thinking skills of secondary school 7th-grade students. In this context, quantitative and qualitative research approaches were used together. In the quantitative dimension of the research, the pretest-posttest experimental control group design was preferred among the quasi-experimental designs. In this direction, 2 experimental groups and 2 control groups were formed. STEM activities were carried out in the experimental groups whilst traditional teaching methods were used in the control groups. In the qualitative dimension of the research, the case study was preferred. With the case study, the subject can be examined in-depth, and a broad perspective on the phenomenon can be provided. 144 7th grade students in Kastamonu province determined by a simple random sampling method participated in the research. Four different public schools were chosen so that student groups would not be affected by each other. Through the quantitative and qualitative data collection tools resorted to in this study, inquiry and innovative thinking skills were examined. The Inquiry Skills Scale (ISS) developed by Aldan-Karademir and Saracaloglu (2013) and the Innovative Thinking Tendencies Scale (ITTS) developed by Deveci and Kavak (2020) were used as quantitative data collection tools. Semi-Structured Observation Form (SSOF) developed by Doganay (2018) and Semi-Structured Interview Questions (SSIQ) developed by Deveci and Kavak (2020) and field notes taken by researchers and those of an independent observer were used as qualitative data collection tools. In light of the findings of the research, it was determined that the students' post-test scores and qualitative application results showed a significant difference in favour of the experimental group. As a result of interviews, observations, and field notes, it was observed that students' inquiry skills and innovative thinking tendencies were not at the expected level, but these skills developed positively with STEM activities.

Keywords: STEM activities; science education; inquiry thinking; innovative thinking

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1. Introduction

STEM education and the activities carried out in this context are applied at many levels, videlicet from primary education to higher education, and it manages to maintain its currency as the central theme in education-teaching models and scientific research. This success can be explained as its innate features that pave the way for incorporating 21st-century skills such as inquiry, problem-solving, creative and innovative thinking, analytical and critical thinking, and some scientific process skills such as observation, experimentation, data collection, model creation, and interpretation. It indeed is emphasized in a fair number of studies that STEM education should be integrated into both formal education and out-of-school learning environments to develop students' inquiry and innovative thinking skills (Sanders, 2008; Sahin, Ayar & Adiguzel, 2014; Schnittka, 2016). In the 2018 Science Curriculum prepared by the Ministry of National Education of Turkey ([MoNE], 2018), it is stated that students' relations with STEM education should be increased, and their experiences should be supported to enhance the technological development capacity of Turkey, to train qualified individuals and to develop socioeconomic development. The concept of STEM, which consists of the initials of the words science, technology, engineering, and mathematics, is one of the innovative education systems that aims to educate students in a versatile and interdisciplinary way in terms of knowledge, skills, and practice (Banks & Barlex, 2014; Oner & Ozdem-Yilmaz, 2019). As it can be understood from the application areas of these subjects, the basis of STEM activities is composed of scientific facts and scientific events. STEM activities, whose popularity has been increasing since 2010, are used efficiently in plentiful schools with a view to fulfilling formal education, non-formal education and distance education (Stohlmann, Moore & Roehrig, 2012; Elnashar & Elnashar, 2019; Abdullateef, 2021). STEM education, which is widely included in the 2018 science curriculum in our country, comprises engineering and design skills (Cavas, Ayar & Gurcan, 2020; Elmas & Gul, 2020). Today, “STEM” and “21st century skills” (Kennedy & Sundberg, 2020; Hadiyanto, Failasofah, Armiwati, Abrar & Thabran, 2021) are amongst the topics frequently used in scientific research and graduate thesis studies (Jang, 2016; Chalkiadaki, 2018; Nakano & Wechsler, 2018; Ghafar, 2020; Kennedy & Sundberg, 2020; Gomez-Parra, 2021; Lavi, Tal & Dori, 2021; Walan, 2021; Yilmaz, 2021). In addition, these concepts are at the top of the themes used in educational activities carried out in schools or within out-of-school learning environments (Balcin & Yavuz-Topaloglu, 2019; Kir, Kalfaoglu & Aksu, 2021). In the World Economic Form ([WEF], 2020), it is emphasized that by 2025, skills gained through STEM education and 21st-century skills will be among the skills of the future.

In the science curriculum prepared in our country to raise qualified individuals, students internalize the novel information they have been exposed to by making connections with similar events in their daily lives (that is the context-based approach)

and improve their ability to solve problems, make decisions, question and criticize, instead of solely memorizing or referring to rote/superficial learning especially as part of mathematics and science-based courses (Gulgun, Yilmaz & Caglar, 2017). In this way, students gain skills such as inquiry (Chu, Reynolds, Tavares, Notari & Lee, 2017), innovative thinking (Barak & Yuan, 2021) and creative thinking (Yudha, Dafik & Yuliati, 2018). Attention that is of rising natüre is paid to STEM activities in the world each day (Cepni, 2018; Johnson & Sondergeld, 2020). It is frequently emphasized that STEM activities develop decision-based thinking skills and cooperation skills, defined as 21st-century skills (Bell, 2010; Narayan, Park, Peker & Suh, 2013; Jang, 2016; Yilmaz, Gulgun & Caglar, 2017). In our country, many means allow the implementation of STEM activities. Some of them are experimental workshops, STEM Maker Fest/Expo applications, science centres, STEM teacher workshops and certification training programs, STEM GameLab activities and competitions. One of the criteria used to determine the level of development of countries is the level of being innovative and productive (Kennedy & Odell, 2014). The concept of innovator is an indicator of thought and progress that has been instrumental in doing things that were not there before. In fact, skills such as innovation, creativity and inquiry are very close concepts with regard to their referants, that is to say, respecting the semantical value they carry (Benton, 2013). At this point, STEM activities come to the fore. Because STEM activities have quite an interdisciplinary structure, they contribute to developing a good number of other skills in a simultaneous fashion in the same environment. All these point to an utterly different perspective than that of the 20th century, when the understanding of literacy (Yanarates & Yilmaz, 2020) was associated with literacy skills and mathematics knowledge.

Today, these life skills and engineering skills are defined as the combination of knowledge, talent and expertise necessary to achieve success in daily/real life (Radloff & Guzey, 2016; Yilmaz, Cetinkaya & Avan, 2019). The rapid progress of science and technology underpins the need for these skills for the near future. It 21st century skills have already taken their place in the basic education policies of many countries assuring each individual develop these skills and be raised as qualified persons creating a qualified workforce (Mahanal, Zubaidah, Bahri, & Dinnurriya, 2016). When examined in general, it is seen that 21st-century skills and STEM activities have common aspects in inquiry, innovative and creative thinking skills. From this point of view, it is thought that focusing on inquiry and innovative thinking skills within the scope of the current research will be a meaningful act that may possibly contribute to the existing scholarly work in the related field. There are numerous studies in the bulk of literature on inquiry and innovative thinking skills. In their study, to illustrate, Deveci and Kavak (2020) examined secondary school students' views and developed the innovative thinking tendency scale. Akgunduz et al. (2015) declared in their STEM education report that it is of great importance to acquire innovative thinking skills within the scope of science

courses and that these practices should be carried out with STEM education. Bakirci and Kutlu (2018) pinpointed that STEM activities aid in the innovative thinking skills of students and teachers. Bahar, Yener, Yilmaz, Emen and Gurer (2018) emphasized that engineering practices integrated into the science curriculum are effective in helping students acquire 21st-century skills as well as inquiry and innovative thinking skills. Oner and Ozdem-Yilmaz (2019) higlighted in their study on inquiry thinking and STEM education that students' inquiry skills improved positively through STEM activities, and STEM education should be used in a frequent manner in science lessons. Kearney (2016) accentuated that science courses are suitable environments to develop students' inquiry skills. It has also been stressed that laboratory practices and classroom activities feed students' sense of curiosity and lead them to question. The Next Generation Science Standards (NGSS, 2013) mentions that inquiry and innovative thinking skills constitute the essential skills that students should have. They underlined that children were intensely open to learning until the high school years and dreamed all the time. It is underscored that the behaviour of asking questions and dreaming improves the creativity and innovative thinking of children (Karakaya, Alabas, Akpinar & Yilmaz, 2020). Although there are plenty of studies on inquiry and innovative thinking skills in the relevant line of literature, not many studies have been found in which both skills are examined together, or where data diversity is ensured. For this reason, it is thought that examining the inquiry and innovative thinking skills of secondary school students by making data diversification with STEM activities will open up a new route to the field. Within the scope of the present research, answers were sought for the following sub-problems:

1. Is there a significant difference between the experimental and control groups' inquiry skills pre-test results?
2. Is there a significant difference between the results of the post-test inquiry skills of the experimental and control groups?
3. Is there a significant difference between the experimental and control groups' innovative thinking tendency pre-test results?
4. Is there a significant difference between the experimental and control groups' innovative thinking tendency post-test results?
5. Is there a significant difference between the results of the post-test inquiry skills of the experimental and control groups in terms of demographic variables?
6. Is there a significant difference between the experimental and control groups' innovative thinking tendency post-test results regarding demographic variables?
7. Under what categories are the observation results, interview results and field notes about the implementation process and the products obtained?

2. Method

In this study, quantitative and qualitative research approaches were used together. There are various reasons for using both approaches. Experimental applications are

mainly carried out with quantitative approaches (Buyukozturk, 2010). Although valid and reliable results are arrived at thanks to these applications, they may be insufficient at the stage of establishing a cause-effect relationship (Fraenkel, Wallen & Hyun, 2012). Qualitative approaches have been included in the process to support this potential weakness of quantitative approaches and boost their research effectiveness (Harden, 2010). In the quantitative dimension of the research, the pretest-posttest experimental control group design was preferred among the quasi-experimental designs (McMillan & Schumacher, 2009). In this context, two experimental groups and two control groups were formed. STEM activities were conducted in the experimental groups. Traditional teaching methods were made use of in the control groups. In the qualitative dimension of the research, the case study was preferred. The subject can be examined in-depth with the case study, and thereupon a broad(er) perspective can be provided on the issue (Patton, 2014; Plano-Clark & Creswell, 2015).

2.1. The Study Design

In the research process firstly, quantitative applications were carried out. However, from time to time, quantitative and qualitative practices were carried out together e.g., in the stages of observation, group work review, and field notes. In the quantitative dimension of the research, STEM activities were carried out for six weeks in the experimental groups. These activities are not limited to a single unit though. Activities were held in the units of *"Solar system and beyond, cell and divisions, force and energy, pure matter and mixtures, the interaction of light with matter, reproduction, growth and development in living things"* (MoNE, 2018, p.39). While the effect of inquiry thinking skills was examined in one experimental group, the impact of inquiry and innovative thinking skills was analysed in the other experimental group. In the control group, the process was carried out with traditional teaching methods. That being said, as in the experimental group, the effect of inquiry thinking skills was examined in one of the control groups, while the impact of inquiry and innovative thinking skills was examined together in the other experimental group. The implementation process is summarized in Table 1.

Table 1. Application process

Groups	**Activities**	**Quantitative**		**Qualitative**		
		Pre-Test	**Post-Test**	**Interview**	**Observation**	**Field Notes**
Experiment 1	STEM Activities	ISS	ISS	SSIQ	SSOF	✓
Experiment 2	STEM Activities	ISS ITTS	ISS ITTS	SSIQ	SSOF	✓
Control 1	Traditional Teaching	ISS	ISS	SSIQ	SSOF	✓
Control 2	Traditional Teaching	ISS ITTS	ISS ITTS	SSIQ	SSOF	✓

When Table 1 is examined, pre-test applications were made in both experimental groups and control groups prior to initiating the applications. *Inquiry Skills Scale (ISS)* and *Innovative Thinking Tendency Scale (ITTS)* were administered to all groups as a pre-test. Six weeks later, the same scales were applied as a post-test this time. Upon the completion of the quantitative applications, qualitative applications were carried out. Within the scope of qualitative applications, *Semi-Structured Interview Questions (SSIQ)* were applied to all groups. The process was fully observed by researchers and an independent observer, and field notes were prepared together with the *Semi-Structured Observation Form (SSOF)*. At the end of the said applications, quantitative and qualitative findings were combined and a report was come up with.

2.2. Participant Characteristics

144 7th-grade students in Kastamonu province of Turkey determined by a simple random sampling method participated in the research. Four different public schools were chosen so that student groups would not be affected by each other. The purpose of selecting students from different schools and determining them randomly is to reduce the error rate that may interfere with the research process and to warrant maximum diversity (Canbazoglu-Bilici, 2019; Cepni, 2012). 36 students from each school participated in the application. It was affirmed that the student's socioeconomic status, cognitive levels, and achievement levels were similar. Demographic characteristics of the students participating in the research are presented in Table 2.

Table 2. Demographic characteristics of the participants

Variables	**Sub-Variables**	**Groups**			
		Exp.1	**Exp. 2**	**Control 1**	**Control 2**
Gender	Female	20	19	15	22
	Male	16	17	21	14
Job Status (Mother)	Working	8	12	7	4
	Not Working	28	24	29	32
Job Status (Father)	Working	32	30	33	28
	Not Working	4	6	3	8
Educational Status (Mother)	Primary School	14	11	11	17
	Middle School	14	12	18	13
	High School	2	1	-	2
	University	6	12	7	4
Educational Status (Father)	Primary School	2	2	2	4
	Middle School	4	2	3	4
	High School	6	4	1	6
	University	24	28	30	22
Computer and Internet Access	1-3 Hour	19	24	22	26
	3-5 Hour	6	5	8	3
	5-7 Hour	7	4	4	3
	Unavailable	4	3	2	4
Scientific Event/Project Participation	Between 1-3	25	23	21	26
	Between 3-5	7	6	11	4
	Between 6-10	1	5	3	3
	Unavailable	3	2	1	3
	Total	36	36	36	36

2.3. Data Collection Tools

Quantitative and qualitative data collection tools were used in this study, through which inquiry and innovative thinking skills were examined. *Inquiry Skills Scale (ISS)* developed by Aldan-Karademir and Saracaloglu (2013) and the *Innovative Thinking Tendency Scale (ITTS)* developed by Deveci and Kavak (2020) were used as quantitative data collection tools. Both scales are available in the literature, and their validity and reliability have been verified. A pilot application was conducted to determine the suitability of the data collection tools for this specific research, and their validity and reliability were examined. The ISS, is prepared in a 5-point Likert type, consists of 14 items and 3 factors. These factors are *acquiring knowledge, controlling knowledge, and self-confidence*. The Cronbach-alpha reliability coefficient for the entire original ISS was found to be .82. The reliability coefficients of the sub-factors were found to be .76, .66 and .82, respectively. As a result of the pilot application of the ISS, the Cronbach-alpha reliability coefficient for the whole scale was found to be .76. The reliability coefficients of the sub-factors were determined as .69, .68 and .73, respectively. The ITTS, prepared in a 5-point Likert type, is made up of 25 items and 5 factors. These factors are *openness to innovation, innovative problem solving, innovative self-efficacy, innovative group leadership and innovative perseverance*. The Cronbach-alpha reliability coefficient was found to be .91 for the entire original ITTS. The reliability coefficients of the sub-factors were found to be .81, .82, .76, .70 and .62, respectively. The Cronbach-alpha reliability coefficient for the whole scale was found to be .85 as a result of the pilot application of the ITTS. The reliability coefficients of the sub-factors were determined as .80, .72, .71, .74 and .66, respectively. It can be announced that the reliability coefficients in question are sufficient in studies conducted in social sciences (Fraenkel, Wallen & Hyun, 2012). *Semi-Structured Observation Form (SSOF)* developed by Doganay (2018) and *Semi-Structured Interview Questions (SSIQ)* developed by Deveci and Kavak (2020), field notes taken by researchers, and an independent observer notes were exploited as qualitative data collection tools. SSOF involves of 20 items. There is an evaluation range of 1-5. SSIQ includes 6 items. The interview time was limited to 5 minutes for each student. Such an approach has been adopted so that the students are not bored, can respond comfortably and express whatever comes to their mind without hesitation- in a quick sense.

2.4. Data Analysis

The data obtained within the scope of the research were subjected to quantitative and qualitative data analysis. Qualitative and quantitative data were analyzed separately. Firstly, quantitative applications were investigated. To this end, the pre-test and post-test application results were scrutinized using the independent samples t-test for two-category variables and the one-way ANOVA test for variables with more than two categories (Can, 2016). Differences between variables were analyzed using the Tukey

significance test (Cokluk, Sekercioglu & Buyukozturk, 2014). Some of the results obtained with the help of the observation form, field notes and interview form are expressed by making direct quotations and via summarizing the responses. The data obtained through qualitative applications were subjected to descriptive and content analysis (Flick, 2009). Since the answers to the interview form were received in written form, they were not re-transcribed. Direct quotations, namely in-vivo coding are also deployed from time to time (Cohen, Manion & Morrison, 2007; Kline, 2004). In the analysis of the aforementioned qualitative data, the coefficient of consensus and disagreement among the evaluators developed by Miles & Huberman (1994) was calculated, and this rate was determined as 84%. Since the rate of consensus of the evaluators was ideal, the Cohen Kappa Coefficient was determined later, and the agreement and collaboration between the evaluators were defined as 89%. These results show that qualitative application data are reliably examined (Krippendorff, 2004; Saldana, 2010).

2.5. Validity and Reliability Measures

The use of quantitative and qualitative applications in the application phase provides relatively more enriched data with the researchers and makes reliability and validity measures possible. The following practices were carried out within the scope of the reliability of the research process (Karasar, 2007; Sozbilir, 2021):

- The opinions of field experts were frequently consulted to for the design of the research process, the determination of data collection tools and application steps.
- Internal reliability can be put forward as the ability of independent researchers to reach similar results using similar data. At this point, direct quotations are occasionally included. To keep the subjective judgments of the evaluators away, the process was managed with three different observers. Findings from interviews were cross checked with the results obtained through observation, and thence their reliability was increased. Discussion of research results within a well-structured conceptual framework is another measure that increases internal reliability. Expressing the research questions clearly and precisely, collecting the data in accordance with the purpose and presenting the results in this regard are also the practicum that increase internal reliability. Coefficients of agreement between independent observers and evaluators were also identified within the scope of reliability measures.
- At the stage of ensuring external reliability, application environments and application processes are described in detail. The researchers took into account the individual differences, prejudices and orientations of the students. In addition, the raw data attained in the research were archived in an appropriate way so that they can be used again later when need be.

The following practices were carried out within the scope of the validity of the research process (Yildirim & Simsek, 2006; Gul & Sozbilir, 2015; Sozbilir, 2021):

- To ensure internal validity, the results of the application were presented as a consistent and meaningful whole. The framework and limitations of the research are clearly defined. A detailed, relevant, and transparent narrative was used during the research data collection, analysis, and interpretation. To ensure external validity, making generalizability effective was taken note of. The research process is explained in detail and clearly so that other researchers can apply it in the future. Finally, the sample was chosen being careful about the fact that it is large enough for generalization.

2.6. Compliance with Ethical Rules and Required Permissions

Necessary application permissions were obtained from the rightful authors for all the data collection tools used in the research, and scientific citations were made as appropriate. In addition to these, the participants were informed about the whole process. The parent consent form and informed consent forms were confirmed for each participant. Within the scope of the research, care was taken to conduct all processes transparently within the framework of ethical rules. Since this research was carried out with secondary school students, ethics committee approval is required. Whence, the required approval was granted by Kastamonu University Social and Human Sciences Research and Publication Ethics Committee (Meeting Date: 01.06.2021 Number: 2 Decision No: 12).

3. Results

In this section, the quantitative and qualitative application results obtained from the research are examined separately. In the quantitative dimension of the research, there are four different study groups, viz. experiment 1, experiment 2, control 1 and control 2, and two different scales are used in this respect. First off, the preconditions of the data were examined. In so doing, extreme values and normal distribution were checked (Can, 2016). During the checks of extreme values, Mahalanobis distances and Z score value ranges between -3 and +3 were studied. As a result of the inquiry, it was observed that Mahalanobis distances and Z scores were in the appropriate value ranges. When the normal distribution of the research results was explored, it was witnessed that the data were mainly in the range of -1 to +1, and only 3 data were in the range of -2 to +2. It is accented that the normal distribution range is accepted between -1 and +1 in social sciences, yet in many sources, it can be between -3 and +3 in cases where the research sample is small (George & Mallery, 2010). Then, the analysis phase was started, and each research question was handled separately. The results for the first problem situation are presented in Table 3.

Table 3. Results for the first problem situation

Groups	**N**	**X̄**	**Sd**	**Df**	**t**	**p**	***Diff.***
Experiment 1 Control 1	36 36	42.55 39.94	7.24 7.66	70	1.486	.142	-
Experiment 1 Control 2	36 36	42.55 41.58	7.24 7.63	70	.554	.581	-
Experiment 2 Control 1	36 36	43.52 39.94	7.72 7.66	70	1.976	.056	-
Experiment 2 Control 2	36 36	43.52 41.58	7.72 7.63	70	1.074	.287	-
Experiment 1 Experiment 2	36 36	42.55 43.52	7.24 7.72	70	.551	.584	-
Control 1 Control 2	36 36	39.94 41.58	7.66 7.63	70	.909	.367	-

p<.05* *Diff:* Difference, t: T-Value for Independent Samples T-Test; *Sd*: Standard Deviation; *Df*: Degrees of freedom.

When the application results were considered, it was found out that the pre-test results of the inquiry skills of all groups were at a similar level, and no significant differences between the scores (p>.05) existed. This is the desired situation in social sciences (Cohen, Manion & Morrison, 2007). It is fundamental in analysing dependent variables that the students participating in the research have similar qualifications before the application (Baykul, 2000; Ozdamar, 2016). Table 4 presents the results for the second problem situation.

Table 4. Results for the second problem situation

Gruplar	**N**	**X̄**	**Sd**	**Df**	**t**	**p**	***Diff.***
Experiment 1 (a) Control 1 (b)	36 36	60.97 53.91	8.08 4.27	70	4.627	.000	a>b
Experiment 1 (a) Control 2 (c)	36 36	60.97 57.86	8.08 5.78	70	1.878	.065	-
Experiment 2 (d) Control 1 (b)	36 36	64.69 53.91	5.44 4.27	70	9.338	.000	d>b
Experiment 2 (d) Control 2 (c)	36 36	64.69 57.86	5.44 5.78	70	5.162	.000	d>c
Experiment 1 (a) Experiment 2 (d)	36 36	60.97 64.69	8.08 5.44	70	2.291	.025	d>a
Control 1 (b) Control 2 (c)	36 36	53.91 57.86	4.27 5.78	70	3.290	.002	c>b

p<.05* *Diff:* Difference, t: T-Value for Independent Samples T-Test; *Sd*: Standard Deviation; *Df*: Degrees of freedom.

When the application results were reviewed, it was determined that the post-test results of questioning skills showed a significant difference (p<.05) between the experimental 1 and control 1, experiment 2 and control 1, experiment 2 and control 2, experiment 1 and experiment 2, control 1 and control 2 groups. It can be pronounced that this difference was mostly in favour of the experimental group. Experimental and control groups also exhibit significant differences within themselves. Table 5 presents the results for the third problem situation.

Table 5. Results for the third problem situation

Gruplar	N	X̄	Sd	Df	t	p	*Diff.*
Experiment 1 Control 1	36 36	72.08 73.97	7.10 8.21	70	1.044	.300	-
Experiment 1 Control 2	36 36	72.08 75.33	7.10 7.84	70	1.842	.070	-
Experiment 2 Control 1	36 36	76.69 73.97	6.55 8.21	70	1.555	.125	-
Experiment 2 Control 2	36 36	76.69 75.33	6.55 7.84	70	.799	.427	-
Experiment 1 Experiment 2	36 36	72.08 76.69	7.10 6.55	70	1.546	.169	-
Control 1 Control 2	36 36	73.97 75.33	8.21 7.84	70	.719	.475	-

p<.05* *Diff:* Difference, *t*: T-Value for Independent Samples T-Test; *Sd*: Standard Deviation; *Df*: Degrees of freedom.

When the application results were examined, it was figured out that the innovative thinking tendency pre-test results were at a similar level for all groups, and there were no significant differences between the scores (*p*>.05). Many studies in the literature support this situation (e.g., Ertugrul-Akyol, 2020; Gulgun, 2020). It is important in the analysis of dependent variables that the students participating in the research have similar qualifications previously, in other words, before the application. The results for the fourth problem situation are presented in Table 6.

Table 6. Results for the fourth problem situation

Gruplar	N	X̄	Sd	Df	t	p	*Diff.*
Experiment 1 (a) Control 1 (b)	36 36	93.11 85.63	15.69 10.92	70	2.344	.022	a>b
Experiment 1 (a) Control 2 (c)	36 36	93.11 89.61	15.69 14.68	70	.977	.332	-
Experiment 2 (d) Control 1 (b)	36 36	103.86 85.63	9.83 10.92	70	7.437	.000	d>b
Experiment 2 (d) Control 2 (c)	36 36	103.86 89.61	9.83 14.68	70	4.838	.000	d>c
Experiment 1 (a) Experiment 2 (d)	36 36	93.11 103.86	15.69 9.83	70	3.482	.001	d>a
Control 1 (b) Control 2 (c)	36 36	85.63 89.61	10.92 14.68	70	1.302	.197	-

p<.05* *Diff:* Difference, *t*: T-Value for Independent Samples T-Test; *Sd*: Standard Deviation; *Df*: Degrees of freedom.

When the application results were evaluated, it was understood that the innovative thinking tendency post-test results differed significantly between the experimental 1 and control 1, experiment 2 and control 1, experiment 2 and control 2, experiment 1 and experiment 2 groups. It can be uttered that this difference was mostly in favour of the experimental group. Besides, whereas the experimental groups demonstrated a significant difference within themselves, there existed no significant difference between the post-test scores of the control groups. The results for the fifth problem situation are presented in Table 7, and the results for the sixth problem situation are displayed in Table 8.

Table 7. Results for the fifth problem situation

	Variable	**Sub-Variable**	***Independent Samples T-Test***				
			$\bar{X}$	*Sd*	*t*	*p*	*Diff.*
Inquiry Skill Experimental Group Post-Test	Gender	Female (1)	61.15	7.89	2.244	.028	2>1
		Male (2)	64.81	5.49			
	Job Status (Mother)	Working	64.15	3.78	.976	.332	-
		Not Working	62.32	7.98			
	Job Status (Father)	Working	63.32	7.28	1.468	.146	-
		Not Working	59.80	5.05			

	Variable	**Sub-Variable**	$\bar{X}$	***One-Way ANOVA*** **Sum of Squares**		*F*	*p*	*Diff.*
Inquiry Skill Experimental Group Post-Test	Educational Status (Mother)	Primary School	63.28	Between Groups	139.14	.918	.437	-
		Middle School	62.19	Within Groups	3436.85			
		High School	69.01	Total	3576.00			
		University	62.11					
	Educational Status (Father)	Primary School	60.01	Between Groups	229.12	1.552	.209	-
		Middle School	68.33	Within Groups	3346.87			
		High School	63.32	Total	3576.00			
		University	62.32					
	Computer and Internet Access	1-3 Hour	61.97	Between Groups	332.50	6.874	.002	2>4 2>1
		3-5 Hour	67.36	Within Groups	3243.49			
		5-7 Hour	62.14	Total	3576.00			
		Unavailable	59.71					
	Scientific Event/Project Participation	Between 1-3	62.47	Between Groups	328.71	7.859	.004	3>4 3>1
		Between 3-5	68.74	Within Groups	3247.28			
		Between 6-10	71.15	Total	3576.00			
		Unavailable	58.17					

	Variable	**Sub-Variable**	***Independent Samples T-Test***				
			$\bar{X}$	*Sd*	*t*	*p*	*Diff.*
Inquiry Skill Control Group Post-Test	Gender	Female (1)	54.13	4.42	2.971	.004	2>1
		Male (2)	57.74	5.82			
	Job Status (Mother)	Working	52.45	4.22	2.352	.021	2>1
		Not Working	56.50	5.41			
	Job Status (Father)	Working	55.37	5.47	1.920	.067	-
		Not Working	58.72	4.36			

	Variable	**Sub-Variable**	$\bar{X}$	***One-Way ANOVA*** **Sum of Squares**		*F*	*p*	*Diff.*
Inquiry Skill Control Group Post-Test	Educational Status (Mother)	Primary School	53.71	Between Groups	247.79	3.047	.034	4>1 4>2
		Middle School	56.77	Within Groups	1843.31			
		High School	57.14	Total	2091.11			
		University	62.29					
	Educational Status (Father)	Primary School	52.67	Between Groups	131.47	1.521	.217	-
		Middle School	52.85	Within Groups	1959.63			
		High School	55.03	Total	2091.11			
		University	56.67					
	Computer and Internet Access	1-3 Hour	55.52	Between Groups	177.85	6.874	.003	3>4 3>1
		3-5 Hour	61.23	Within Groups	1913.25			
		5-7 Hour	67.85	Total	2091.11			
		Unavailable	51.04					
	Scientific Event/Project Participation	Between 1-3	55.53	Between Groups	161.42	7.419	.012	3>4 3>1 2>4
		Between 3-5	61.76	Within Groups	1929.68			
		Between 6-10	69.52	Total	2091.11			
		Unavailable	52.07					

$p<.05$* *Diff:* Difference, *t*: T-Value for Independent Samples T-Test; *F: F-Value for One-Way ANOVA.*

Table 8. Results for the sixth problem situation

Innovative Thinking Tendency Experimental Group Post-Test

Variable	Sub-Variable	*Independent Samples T-Test*				
		X̄	*Sd*	*t*	*p*	*Diff.*
Gender	Female (1)	94.92	16.40	2.411	.019	2>1
	Male (2)	102.69	9.32			
Job Status (Mother)	Working	97.20	19.15	.478	.634	-
	Not Working	98.98	11.77			
Job Status (Father)	Working	104.80	10.91	3.145	.001	1>2
	Not Working	97.46	14.34			

Variable	Sub-Variable	*One-Way ANOVA*					
		X̄	Sum of Squares		*F*	*p*	*Diff.*
Educational Status (Mother)	Primary School	94.92	Between Groups	757.92	1.289	.285	-
	Middle School	98.23	Within Groups	13330.06			
	High School	103.66	Total	14087.98			
	University	102.94					
Educational Status (Father)	Primary School	81.70	Between Groups	4886.07	12.036	.000	4>1 4>2 3>1
	Middle School	98.98	Within Groups	9201.91			
	High School	111.16	Total	14087.98			
	University	115.87					
Computer and Internet Access	1-3 Hour	96.44	Between Groups	607.30	11.084	.003	3>1 3>4
	3-5 Hour	99.18	Within Groups	13480.68			
	5-7 Hour	104.45	Total	14087.98			
	Unavailable	86.87					
Scientific Event/Project Participation	Between 1-3	96.81	Between Groups	444.23	8.754	.011	3>1 3>4
	Between 3-5	101.45	Within Groups	13643.75			
	Between 6-10	108.46	Total	14087.98			
	Unavailable	92.14					

Innovative Thinking Tendency Control Group Post-Test

Variable	Sub-Variable	*Independent Samples T-Test*				
		X̄	*Sd*	*t*	*p*	*Diff.*
Gender	Female (1)	86.02	11.03	1.073	.287	-
	Male (2)	89.13	14.78			
Job Status (Mother)	Working	90.90	10.21	.909	.365	-
	Not Working	87.03	13.43			
Job Status (Father)	Working	101.36	7.44	4.236	.000	1>2
	Not Working	85.14	12.25			

Variable	Sub-Variable	*One-Way ANOVA*					
		X̄	Sum of Squares		*F*	*p*	*Diff.*
Educational Status (Mother)	Primary School	72.50	Between Groups	2814.72	6.938	.000	4>1 4>2
	Middle School	84.78	Within Groups	9196.14			
	High School	86.29	Total	12010.87			
	University	101.36					
Educational Status (Father)	Primary School	79.28	Between Groups	1816.26	4.038	.011	4>1 4>2
	Middle School	79.11	Within Groups	10194.61			
	High School	99.16	Total	12010.87			
	University	105.12					
Computer and Internet Access	1-3 Hour	89.41	Between Groups	2365.95	5.560	.002	3>1 3>4
	3-5 Hour	96.54	Within Groups	9644.92			
	5-7 Hour	103.54	Total	12010.87			
	Unavailable	87.65					
Scientific Event/Project Participation	Between 1-3	86.34	Between Groups	3071.30	7.787	.000	3>4 3>1
	Between 3-5	98.33	Within Groups	8939.57			
	Between 6-10	108.75	Total	12010.87			
	Unavailable	81.73					

p<.05* *Diff:* Difference, *t*: T-Value for Independent Samples T-Test; *F: F-Value for One-Way ANOVA.*

When Table 7 is examined, it was discerned that there was a significant difference merely in the gender variable [$t_{(70)}$=2.244, p=.028<.05] due to the independent samples t-test conducted for the experimental group of the post-test scores of inquiry skills. When the gender variable is looked into, it is discovered that the significant difference is in favour of male students. The job status of the mother and father did not make a significant difference. When we look at the results of the one-way ANOVA test, it is ascertained that the mother [$F_{(3\text{-}68)}$=.918, p=.437>.05] and father [$F_{(3\text{-}68)}$=1.552, p=.209>.05] education level variables do not make a significant difference. When the computer and internet access variable is delved into, it is discerned that the students who use it for 3-5 hours [$F_{(3\text{-}68)}$=6.874, p=.002<.05] differ significantly from the students who have no access and the students who use it for 1-3 hours. In a similar vein, in the variable of the scientific activity or project participation, it is realized that the students who participated in 6-10 activities [$F_{(3\text{-}68)}$=7.859, p=.004<.05] differed significantly from the students who did not participate in any activity and participated in 1-3 activities. As a result of the independent samples t-test performed for the control group, it was uncovered that there was a significant difference in the variables of gender [$t_{(70)}$=2.971, p=.004<.05] and mother job status [$t_{(70)}$=2.352, p=.021<.05]. When the gender variable is examined, it is deduced that the significant difference is in favour of male students, while the significant difference is in favour of mothers who do not work. The father's job status did not make a significant difference. Considering the results of the one-way ANOVA test, only the father's educational status [$F_{(3\text{-}68)}$=1.521, p=.217>.05] does not make a significant difference. When the mother's educational status variable is dwelled upon, it is unearthed that the mothers who are university graduates make a significant difference [$F_{(3\text{-}68)}$=3.047, p=.034<.05] compared to the mothers who are primary and secondary school graduates. When the computer and internet access variable is descried, it is detected that the students who use it for 5-7 hours [$F_{(3\text{-}68)}$=6.874, p=.003<.05] differ significantly from the students who have no access and the students who use it for 1-3 hours. As for the variable of the scientific activity or project participation, it is noticed that the students who took part in the activities between 6-10 [$F_{(3\text{-}68)}$=7.419, p=.012<.05] differ significantly from the students who were not involved participate in any activity and participated in 1-3 activities, and the students who participated in the activities between 3-5 made a significant difference compared to the students who did not participate in any activity.

When Table 8 is pondered, it was viewed that there was a significant difference in the variables of gender [$t_{(70)}$=2.411, p=.019<.05] and father's job status [t(70)=3.145, p=.001<.05] due to the independent samples t-test made for the experimental group of the post-test scores of innovative thinking tendency. When the gender variable is researched, it is noted that the significant difference is in favour of male students, while the significant difference in the father's job status is for working fathers. The mother's job status did not make a significant difference. With regard to the results of the one-way

ANOVA test, it is encountered that only the mother's educational status [$F_{(3\text{-}68)}$=1.289, p=.285>.05] does not make a significant difference. It is corroborated that the father educational status [$F_{(3\text{-}68)}$=12.036, p=.000<.05] variable creates a significant difference, and this difference is in favour of university graduates and high school graduates. When the computer and internet access variable is inspected, it is found that the students who use it for 5-7 hours [$F_{(3\text{-}68)}$=11.084, p=.003<.05] differ significantly from the students who have no access and the students who use it for 1-3 hours. Similarly, in the variable of the scientific activity or project participation, it is recognized that the students who participated in 6-10 activities [$F_{(3\text{-}68)}$=8.754, p=.011<.05] differed significantly from the students who did not participate in any activity and participated in 1-3 activities. As a result of the independent samples t-test for the control group, it was interpreted that there was no significant difference in the variables of gender [$t_{(70)}$=1.073, p=.287>.05] and mother's job status [$t_{(70)}$=.909, p=.365>.05]. The father's job status [$t_{(70)}$=4.236, p=.000<.05] variable, on the other hand, created a significant difference in favour of working fathers. The following enlist the results of the one-way ANOVA test. First, it is inferred that there is a significant difference in the mother's educational status [$F_{(3\text{-}68)}$=6.938, p=.000<.05], father's educational status [$F_{(3\text{-}68)}$=4.038, p=.011<.05], computer and internet access [$F_{(3\text{-}68)}$=5.560, p=.002<.05] and scientific activity [$F_{(3\text{-}68)}$=7.787, p=.000<.05] variables. These differences were in favour of those who were university and high school graduates for their parents' educational status. When the computer and internet access variable is enquired, it is comprehended that the students who use it for 5-7 hours differ significantly from the students who have no access and the students who use it for 1-3 hours. As regards the scientific activity or project participation, it is seen that the students who participated in 6-10 activities differed significantly from the students who did not participate in any activity and participated in 1-3 activities. The last problem situation of the research was prepared for qualitative applications.

Figure 1. Individual applications and sample materials

Figure 2. Group work and sample materials

As can be seen in Figure 1 and Figure 2, students carry out individual and group activities, and as a result of these activities, they prepare materials for several different units. The field notes and observation results received by the researchers and by an independent observer during all these activities are listed below:

- It was specified that the students did not have a very high sense of curiosity when they started the activities, and they even showed shy behaviour. It was noted that as the products started to emerge in the process, their motivation level increased, and they wanted to continue the activity without a time limit. This situation reflected positively on students' behaviour towards science lessons.
- It has been observed that the students have improved over time in the activities that need to use their psychomotor skills and fine motor muscles, and they have begun to use many materials comfortably and without assistance.
- As the difficulty level of the prepared STEM activities increased, so did the inquiry behaviours of the students, and they frequently exchanged opinions to present different products while designing.
- Some of the STEM activities were carried out in the school environment and some in the out-of-school settings. In particular, students were asked to design and report when they came up with an idea after school. In this way, it has been tried to provide suitable environments for developing innovative thinking and inquiry skills without the limitations of time and space.

- STEM activities prepared under the guidance of teachers have not always been executed by sticking to a plan or program. While preparing some activities, students' opinions were consulted, and these were shaped together with them. This approach enabled students to be (more) involved in the process and also helped them develop alternative ideas.
- STEM activities positively affected students' communication level and cooperative working behaviours. This situation allowed the emergence of new behaviours such as task distribution and responsibility-sharing.
- Since the applications were carried out in out-of-school environments, this also contributed positively to the students' ability to access information sources and to their inquiry skills.
- The most striking point coming out of the observations is that the students constantly generate ideas and come to the lesson with new design ideas.
- This shows that STEM activities trigger feelings of inquiry, research and discovery in students, and they have self-confidence in producing innovative ideas.

Finally, the answers given by the students to the interview questions were screened. The answers given by the students to question *"What do you understand by the term innovation?"* are as follows:

S2: "I think innovation is generating different ideas. They are different ideas that no one has thought of before and have emerged for the first time."

S9: "Innovation is to produce valuable and cheap things for people. I want everyone to be able to buy and use the product."

S14: "These activities, which our teacher have done in the lessons, can be innovative. We have never had this much fun in our classes before. I don't want the lesson to end now."

As can be seen, students define the concept of innovation as producing different ideas and teaching unusually. The responses made by the students to the question directed: *"Do you see yourself as an innovative individual?"* are as follows:

S11: "I don't see myself as an innovator. But after having participated in these activities, I think I want to make innovative designs."

S26: "I didn't know much about innovation. Frankly, I had never thought about something like this before. If it is producing useful things for myself and the people around me, I would like to be innovative."

S41: "Our teacher always encouraged us. I think I'm a little bit innovative. Because now I can easily do an experiment and design at home."

Students stated that they had self-confidence problems before these activities and did not think much about being innovative. These activities help them develop a different perspective. The answers given by the students to the question posed: *"Have you developed a new product or design?"* are as follows:

S18: "Yes, we have prepared new products both individually and with our friends."

S33: "Some activities were aimed at essential product development. However, a few really caught my attention. I couldn't wait to see the result."

S54: "In the science class, our teacher usually conducted the experiments, and we watched them. But today we've done it, and our teacher's watched us. I've felt like a teacher. It's a great feeling to prepare materials and then display them."

When students prepared a new product or focused on a topic that was interesting to them, they were willingly involved in the process. This situation enabled them to be a part of the activity and the lesson process and developed their sense of belonging. The answers given by the students to the question: *"How do you think it feels to question, research and criticize?"* are as follows:

S29: "I'm not someone who asks a lot of questions. However, while doing these activities, I asked so many questions. Sometimes I asked questions to my family, sometimes to my teacher, and sometimes to my classmates."

S63: "I don't like to question and criticize. But it is gratifying to do these as part of a scientific process and to use them while developing materials. I feel like I'm in the middle of a maze, and all I can do is ask questions and find the way out."

S66: "I was terrified that my teacher would get angry if I asked a question. However, during the activities, our teacher asked us to ask questions and produce solutions constantly. In this way, I have started to overcome my shyness."

When the students' answers were checked, it was seen that they had reservations to ask questions and had negative thoughts about cooling off and making criticism. Howbeit, STEM activities assist in creating a more comfortable environment for students and allow them to express their opinions freely. The answers given by the students to the question: *"What kind of a relationship do you think there is between the ability to inquiry and the tendency to innovative thinking?"* are as follows:

S17: "To learn and produce something new, it is necessary to read, question and research. If you want to create different designs or different products, you should do things differently- different from everyone else. You have to inquire into it. I think we should constantly inquire into things and generate ideas."

S31: "Some of the STEM activities were too complicated for me. That's why I always felt the need to ask questions. I realized that while I was designing something new, I was constantly asking questions to someone. That's why I think relationships are crucial."

S70: "Our teacher said that new ideas come with further questions. We ask ourselves these questions first. We then share them with others to develop new thoughts in our minds. I think we cannot generate new ideas or create new products if we do not inquire into them."

Students punctuate that they understand the importance of inquiry to create innovative ideas. They articulate that they constantly ask questions while creating new products, and this is a prerequisite. The answers given by the students to the question: *"Are there people around you who have high questioning skills and innovative thinking skills?"* are as follows:

S60: "Yes, I can give my sister as an example. My sister is curious and asks a lot of questions. Sometimes she has such different ideas that I can't help but be surprised. This means that this situation is related to inquiry and asking questions."

S30: "Our teacher asks us a lot of questions. When we finish a topic, we repeat it all the time. We are preparing events. Now I understand that our teacher has to do these while teaching us something new."

S72: " I watch many videos online. This gives me a wide variety of ideas. While doing STEM activities, my friends are constantly asking me, where I find these ideas that are so good. I was constantly watching videos and inquire into many things without realizing it."

4. Discussion and Conclusions

In this study, which examines the inquiry skills and innovative thinking tendencies of secondary school 7th-grade students, many new results that support and differ from the relevant literature have been obtained. Two different experimental groups and two different control groups were formed in the study. In the first of the experimental and control groups, only the students' inquiry skills were tried to be measured. In the other experimental and control groups, inquiry skills and innovative thinking skills were measured together. Before starting the research, two different scales were applied to check that all groups were homogeneous and at similar cognitive levels. The pre-test results showed no significant difference between the experimental and control groups and that there were students with similar qualifications (homogeneous) (Please see. Table 3 and Table 4 above). STEM activities for six different units were carried out for six weeks. During these activities, observations were made, and field notes were kept. Then, two different scales were applied as post-test. When the post-test results of inquiry thinking skills are examined, it is seen that there is a significant difference in favour of the experimental groups. In the classrooms where STEM activities were applied, the inquisitive thinking tendencies of the students showed a higher level of change. These results are supported by many studies in the literature (e.g., Crawford, Zembal-Saul, Munford & Friedrichsen, 2005; Brickman, Gormally, Armstrong & Hallar, 2009; Chen, 2010; Chen, Chang, Lai & Tsai, 2014; Kaya, 2020; Kenar, 2020; Buyuran, 2021; Kapici, 2021; Woods-Groves, Choi, & Balint-Langel, 2021).

With that being said, there is another result that differs. In both the experimental and control groups, the groups in which both skills (inquiry and innovative thinking) were

measured together had higher averages. This shows the existence of a positive relationship between inquiry and innovative thinking skills. A limited number of studies have been found in the literature explaining this situation (De Jong, Sotiriou & Gillet, 2014; Furtak, Seidel, Iverson & Briggs, 2012). This result is a result that can contribute to the related field. Some skills of children at the secondary school level which are expressed as 21st-century skills can be nurtured in individuals through a single behaviour change. Since STEM Activities have an interdisciplinary structure, they also support the development of these skills in the same environment and simultaneously (Hovardas, Xenofontos & Zacharia, 2017). These results have again confirmed how successful STEM activities are in interdisciplinary interaction (Kirici, 2019; Yerlikaya, 2019).

When the post-test results of the students' inquiry skills are analyzed in terms of demographic variables, it is seen that there are significant differences in the variables of gender and mother's job status. Gender is an essential variable in STEM practices (Kirschner, Sweller & Clark, 2006; Baram-Tsabari & Kaadni, 2009). In these applications, where engineering, design skills and psychomotor skills come to the fore, it is seen that male students are more effective and can adapt to the applications more easily (Khishfe & BouJaoude, 2016). When the mother job status variable is examined, it is seen that the children whose mothers are not working have higher averages. This can be explained by how much time students spend with their families. Working mothers spend less time with their children than non-working mothers. This situation indirectly affects students and partially reduces their inquiry activities while designing something new. When the educational status of the mother and father were examined, it was determined that only the educational status of the mother showed a significant difference, and this difference was in favour of university graduates. The ability to question is directly proportional to the life of individuals and the knowledge and experiences they are engaged in their environment. Many studies (e.g., Lazonder & Ehrenhard, 2014; Lazonder & Harmsen, 2016) show that curious and creative individuals have intense experiences and are constantly exposed to different types of information. As the duration of computer and internet access increases, the students' inquiry skills increase, reaching the highest level between 5-7 hours. It goes without saying that the world of internet is like an endless sea in terms of providing information. Students can access millions of pages about a subject they want to explore and gain a wide variety of experiences. The literature supports these results (Mayer, 2005; Sorden, 2012; Yanarates, 2020). As the rate of participation in scientific activities and projects increases, as in computer and internet access, it is seen that there is significant differentiation in students' inquiry skills. Scientific activities are the environments where students are most comfortable, asking questions and satisfying their curiosity. For this reason, it is expected that inquiry skills will increase as the frequency of participation in activities increases (De Jong & Lazonder, 2014; Gulgun, Yilmaz, Avan, Ertugrul-Akyol &

Doganay, 2019). When the students' innovative thinking tendency post-test results are examined, it is seen that similar results are reached with the results of inquiry skills. There was no significant difference between the pre-test results of the experimental and control groups. These results reveal that the innovative thinking tendencies of the students before the applications are in a homogeneous structure. Innovative thinking post-test results show a significant difference in favour of the experimental groups. On the other hand, some results that support the post-test results of inquiry skills and that are thought to contribute to the literature were also found in this section. When the results favouring the experimental and control groups were examined, the groups in which both skills were measured together had higher averages. This hints at that some skills support each other and are acquired more effectively in the same educational environment (Arafah, 2011; Banks & Barlex, 2014; Abbak, 2018; Yuksel, 2020).

When the post-test results of students' innovative thinking tendency are analyzed in terms of demographic variables, it is seen that there are significant differences in favour of gender and father's job status. As in inquiry skills, male students had higher averages in innovative thinking tendency. In the literature, it has been reported in many studies that women are more successful than men in innovative and creative thinking tendencies (Capraro & Slough, 2008; Runco, Cramond & Pagnani, 2010; Bicer, 2018). These results differ according to the literature. In the inquiry skill, while the mother's job status differs, if the father's job status is inclined to innovative thinking, the father's job status shows a significant difference, which is in favour of working fathers. Fathers are role models for their children. Therefore, it can be stated as a result of this research that working fathers are more exemplary for their children in producing something new (Taylor & Barbot, 2021). In the questioning skill, only the education level of the mother showed a significant difference. In contrast, the educational status of both the mother and the father showed a significant difference in the innovative thinking tendency. These results cast light to certain characteristics of innovative and creative individuals. A creative learning environment, an innovative family and getting a good education support these results (Siburian, Corebima, Ibrohim & Saptasari, 2019; Ayyildiz & Yilmaz, 2021). Environmental factors such as socioeconomic levels, cultural activities, orientation to education and motivational levels of children whose parents are university graduates may differ. Hence, it can be said that these differences also affect the skills and tendencies of the students over time. It is seen that as the duration of computer and internet access increases, students' innovative thinking tendencies increase, and this period reaches the highest level between 5-7 hours. Students are most often interested in internet environments instead of reading books to watch, research or design something new (Lee & Kemple, 2014). Because the internet environment has digital content that is easily accessible, it provides multimedia-rich content and keeps students' curiosity high at all times. Consequently, it is acceptable that students' innovative thinking tendencies increase positively as the duration of computer access and internet use increases. As the

rate of participation in scientific activities and projects increases, as in computer and internet access, students' innovative thinking tendencies also differ significantly. Scientific activities and projects often have products and content that cannot be dealt with in the classroom environment. In this framework, when students participate in science fairs, science competitions or scientific events, they hope to learn something new and have a higher level of motivation (Gulgun et al. 2019).

When the qualitative application results obtained as a result of the research were examined, it was seen that there were some remarkable points. To cite an example, the students did not have a high level of curiosity when they started the activities, and they even showed shy behaviour. It has been determined that as the products begin to emerge in the process, their curiosity and motivation levels increase (Aydin, 2007). Addedly, it has been observed that there is an improvement over time in the activities that students need to use their psychomotor skills. As the difficulty level of the prepared STEM activities increased, the inquiry behaviours of the students increased, and they frequently asked each other questions to make different designs. While planning STEM activities, sometimes students' opinions were also consulted. This has helped them take more responsibilities and be absorbed in the process more deeply. STEM activities positively affected students' communication level and cooperative working behaviours (Baran, Canbazoglu-Bilici & Mesutoglu, 2017). They especially felt the need to distribute tasks. This situation led students to question whether they should study systematically. The most striking point among the observations is that the students constantly produce new and different ideas and come to the lesson with new design ideas. Students often enunciated that they had new projects and ideas before they started the lesson and wanted to share them in the lesson. STEM activities have undertaken a task that triggers the feelings of inquiry, research and discovery in students and enable them to have self-confidence in producing innovative ideas (Cetin & Bulbul, 2017). These results are also supported by the interview results.

5. Reflections and Implications

Some important points that emerged as a result of the research are given below:

- Male students achieved higher levels of positive results than female students in inquiry and innovative thinking skills.
- The educational status of mother and father are factors that indirectly impact inquiry and innovative thinking skills.
- Computer and internet access contribute to the development of students' skills within the scope of STEM activities.
- The rate of participation in scientific activities and projects positively affects students' inquiry and innovative thinking tendencies.
- Science lessons taught with STEM activities increase students' motivation, develop

their sense of curiosity, support cooperation and teamwork skills, and create learning environments suitable for developing their inquiry and innovative thinking skills.

- Interviews, observations and field notes showed that students have a high potential for STEM applications, and this potential is ready to be revealed if appropriate environments are provided.
- Secondary school is a transition period between primary and high school education, and many skills are open to development. In this period, it was seen that inquiry and innovative thinking tendencies should be supported seriously.

6. Limitations and Future Research

This research was carried out with a limited sample. Skill and behaviour-based studies can ideally be longer-term and thusly can be done at a longitudinal level. At this point, the limited aspect of the study is that it is limited to a period of 6 weeks and is a cross-sectional study. As the research variables, competence levels in subjects such as school opportunities, teacher skills and abilities, digital literacy and 21st-century skills can be used in future research. It may be recommended to repeat this study with larger samples using long-term activities.

Declaration of Competing Interest

The authors herein report that they have no conflict of interest.

CRediT Authorship Contribution Statement

Ph.D. Adem YILMAZ: Methodology, Investigation, Software, Validation, Data Collection, Formal Analysis, Visualization, Writing - Review & Editing.

Ph.D. Erkan YANARATEŞ: Conceptualization, Writing - Original Draft, Writing - Review & Editing, Project Administration.

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